REDUCING PACKET LOSS IN FAST HANDOVER FOR MOBILE IPv6 (FMIPv6) BY USING ADAPTIVE PACKET BUFFERING TUNING ALGORITHM

ANESA MAOLOD OMAL AL-NAJEH

A dissertation submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Science (Computer Science)

Faculty of Computer Science and Information Systems
Universiti Teknologi Malaysia

MARCH 2012

I dedicate this thesis to the following special people:

My Beloved Husband;

To my heartthrob and exquisite hubby Al-Mukhtar; your love and inspiration mould me

My Beloved Daughter;

To my pretty one Simar; our bundle of joy.

My Beloved Parents;

To my parents: my beloved mother Amina, to my late father Maolod, and to my beloved grandmother Reem; who have molded me into who I am; without their patience, understanding, support, and most of all love, the completion of this work would not have been possible and for their invaluable sacrifice.

Sisters;

Amel, Warda (Rose), Amany (Manny), Dekra, Entesar, Salwa, and Reem

Brothers;

Osama (his wife Hanan), Aimen (his wife Hala), Mohammed, and Ahmed

And to all my aunts and uncles and the rest of my relatives.

May the Mercy and Blessings of Allah shower upon all of you Amiin.

I love you all so dearly

ACKNOWLEDGMENT

"ALL THANKS DUE TO ALLAH THE LORD OF THE WORLDS"

First and foremost, I am grateful to ALLAH on his blessing in completing this thesis.

Second, I wish to express my sincere appreciation to my research supervisor *Assoc. Prof. Dr. Kamalrulnizam Abu Bakar* for encouragement, precious, and critics. Without his continued support and interest, this thesis would not have been the same as presented here. And for this vision, guidance and support throughout the duration that I undertook to complete this thesis successfully. Again my appreciation goes to *Mr. Ali Safa Sadiq (Phd)* and *Muhammed Arif Amin (Phd)* for their relentless efforts and contributions during my research work.

Third, my appreciation goes to my husband *Al-Mukhtar Ali* who stood by my side all that long. I found an ear to listen and a shoulder to lean on. Words cannot express how much I am thankful for him. Next my sincere appreciation goes to my daughter, *Simar*, whom I feel that she was deprived of kindness and care throughout the writing of thesis.

Last but not least, I would like to thank my parents and my siblings that have given their moral support during the ups and downs of my research work life cycle.

ABSTRACT

Recently the technological growth has made the world to become mobile. People have started communicating using wireless enabled devices such as Mobile phones and laptops. Most of these devices are used to communicate over the wireless networks, which allow users to be mobile; this trend has introduced the concept of mobility, which allows users to communicate anytime anywhere. However, a mobile node (MN) cannot receive IP packets based on its new point of attachment until the handover is completed. Mobile Internet Protocol (MIP), Mobile IP version 4 (MIPv4), and Mobile IP version 6 (MIPv6) has been proposed by Internet Engineering Task Force (IETF) to leverage mobility for wireless users but suffers from handover latency which causes the packet loss. The packet loss has become once such important issue to the research world, which needs to be resolved. As an extension of the MIPv6 protocol, Fast handover in Mobile IPv6 (FMIPv6) aims to eliminate handover latency and reduce the number of packet loss. FMIPv6 addresses the ability of a MN to send packets immediately when it detects a new subnet link, and the ability of an access router to deliver packets to a MN directly when the MN attachment is detected. Achieving these points will reduce the handover latency, by eliminating the unreachability of the MN as it will be able to receive packets during handover. In this research, an adaptive packet buffering tuning algorithm based on priority and traffic throughput is designed to reduce packet loss in FMIPv6. In addition, high level of throughput and low delay can be achieved through the proposed technique. A network simulator OMNET++ is used along with the FMIPv6 to develop the model and the algorithm. The evaluation of the proposed algorithm will be done using the performance metrics such as packet loss, throughput, and delay to evaluate the performance and justify the research objectives. In terms of overall packet loss, the APT approach performs the best, with as much as a 49% decrease and improvement compared with ALT algorithm.

ABSTRAK

Kini, perkembangan teknologi telah menyebabkan kita mengguna peranti tanpa wayar di mana jua. Kebanyakkan peranti berkomunikasi melalui rangkaian tanpa wayar. Ini menyebabkan kita mudah alih semasa berkomunikasi dari mana jua. Walau bagaimanapun, nod bimbit tidak dapat menerima paket Internet Protokol (IP) berdasarkan lampiran baru sehingga penyerahannya lengkap. *Mobile Internet Protocol (MIP), Mobile IP version 4 (MIPv4)* dan *Mobile IP version 6 (MIPv6)* telah dicadangkan oleh *Internet Engineering Task force (IETF)* untuk memanfaatkan kegunaan dari peranti tanpa wayar tetapi ia mengalami penyerahan lambat akibat kehilangan data paket. Kehilangan data paket adalah isu penting dalam penyelidikan yang perlu diselesaikan serta-merta. Lanjutan dari Protokol *MIPv6, Fast Mobile IPv6 (FMIPv6)* bertujuan untuk menghapuskan penyerahan lambat dan kehilangan data paket. *FMIPv6* berkeupayaan meningkatkan masa penyerahan apabila ia mengesan pautan subnet dan mengakses router untuk menghantar paket ke nod bimbit apabila lampiran nod bimbit dikesan. Ini akan mengurangkan penyerahan yang lambat dengan menghapuskan ketidaksampaian paket. Kajian ini, memperkenalkan *adaptive buffering tuning* algoritham berdasarkan keutamaan dan trafik untuk mengurangkan kehilangan paket di *FMIPv6.* Rangkaian simulasi *OMNET++* telah digunakan dengan *FMIPv6* untuk membangunkan model dan algoritham. Penilaian keputusan berdasarkan kehilangan data dan masa penyerahan. Kesimpulan kajian ini, *APT* telah melaksanakan dengan baik dengan kemerosotan 49% dan peningkatan berbanding *ALT* algoritham.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

3G	3rd Generation Mobile Telecommunications
AF	Assured Forwarding
ALT	Adaptive Buffer Limit Tuning Algorithm
AP	Access Point
APT	Adaptive Packet Buffering Tuning Algorithm Based on Priority and Traffic Throughput
AR	Access Router
B	Buffer
BA	Binding Acknowledgment
bps	bits per second
BR	Binding Request
BU	Binding Update
CBR	Constant Bit Rate
cCoA	current Care-of Address
CN	Correspondent Node
CoA	Care-of Address
CDMA	Code Division Multiple Access
CISCO	Computer Information System Company
DAD	Duplicate Address Detection
DF	Default Forwarding
DiffServ	Differentiated Services
EF	Expedited Forwarding
FA	Foreign Agent
F-Back	Fast handover Acknowledgment
FBU	Fast Finding Update
FIFO	First In First Out

FMIPv6	Fast Handovers Mobile IPv6
GSM	Global System for Mobile Communications
HA	Home Agent
HMIPv6	Hierarchical Mobile IPv6
HoA	Home of Address
IEEE	Institute for Electrical and Electronic Engineers
IETF	Internet Engineering Task Force
IP	Internet Protocol
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
L2	Layer 2 (Link Layer)
L3	Layer 3 (Network Layer)
LBU	Local Binding Update
LCoA	Local Care-of-Address
LT-Buffer	Link-Triggered Buffer
m	meter
MAP	Mobility Anchor Point
Mbps	Mega bits per second
MIP	Mobile Internet Protocol
MIPv4	Mobile Internet Protocol version 4
MIPv6	Mobile Internet Protocol version 6
MN	Mobile Node
ms	millisecond
nAP	new Access Point
NAP	New Access Point
NAR	New Access Route
newAR	new Access Router
nCoA	new Care-of-Address
NS-2	Network Simulator
oldAR	old Access Router
oCoA	old Care-of-Address
OMNET++	Object-Oriented Modular Discrete Event Network Simulator
OPNET	Operations Network

P	Packet
PAP	Previous Access Point
PAR	Previous Access Router
PHB	Per-Hope-Behavior
q	queue
QoS	Quality of Service
RCoA	Regional Care-of-Address
RSVP	Resource Reservation Protocol
s	second
Sec	Second
S-Mobile IP	Standard Mobile IP
t	Time
TB	Tunnel Buffering
TCP	Transmission Control Protocol
UMTS	Universal Mobile Telecommunications System
VBR	Variable Bit Rate
VoIP	Voice over Internet Protocol
WFQ	Weighted Fair Queueing
WiFi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network

CHAPTER 1

INTRODUCTION

1.1 Overview

Today, the world has become more and more mobile and the nodes are wirelessly connected with each other. This emerging technology allow us to operate freely without any wire attached and can be done across between nodes and access points in the same communication range. Wireless technology such as Wi-Fi, WiMAX, 3G and many more are being used for fast communication such as email or video conferencing, while technology such as GSM, UMTS and CDMA are used to perform real-time communication services, for example, voice calls or video calls. However, both of the technologies have limitations in terms of bandwidth capacity and range of coverage.

The users of the Internet are increasing very rapidly also, they required higher bandwidth in order to cope with their work demand, especially in the wireless internet environment. However, the third-generation (3G) networks which provided them such services have downsides such as delays and low data rate transfer. In that sense, cellular operators are looking for a much faster solution but inexpensive to implement, to deal with the demands from the users. Therefore, technology such as WLAN is being looked into to complement the cellular networks such as 3G to minimize the network delay and provide a much faster data transfer rate.

Mobile computing provides mobile users flexible means of communication anytime anywhere. However, it includes the requirement that ongoing session should not break when the user is moving from one point of attachment to other. Internet Protocol (IP) was originally designed for the fixed networks. IP addresses were associated with fixed network computers and were required to be unchanged for the current session, but if the user moves to a different network, the computer is rebooted to gain network connectivity by obtaining a new IP address. Therefore, it is to satisfy the requirements of the mobile users.

The Internet Engineering Task Force (IETF) was formed to create a protocol for providing and managing the connectivity of hosts, while they are moving between networks. This protocol is called Mobile IP. The first version of Mobile IP protocols was Mobile IPv4 (Perkins, 2007). The main aim of the mobile IPv4 is to provide the connection for Mobile Node (MN) when it exists in a foreign domain, using two addresses, Home Address (HoA) and Care-of Address (CoA). The MIPv4 also was designed to handle mobility to IPv4 users which were mainly fixed nodes users, but due to the address space restriction in IPv4 the IETF was designed to work on a new upgraded mobile protocol version of IP called IPv6 (Wang, Hsu, and Lai, 2004).

Mobile IPv6 allows nodes to remain reachable while moving towards the network. The Mobile IPv6 (MIPv6) has some features that make it more efficient than Mobile IPv4 from many aspects. It sustains real time traffic connecting the Mobile Node (MN) and Correspondent Node (CN) (Zaki, 2008). MIPv6 offers transparent host mobility included in IPv6 address (Zhao and Nie, 2009, Wu and Nie, 2009). The protocol guarantees the free movement of the Mobile Nodes among networks without changing its IPv6 address.

Mobile IPv6's performance was improved through sum of mobility protocols, particular concerning handoff or handover processes where these protocols are mostly used for environments having not enough specifications like data delivery delay, packet loss, and signalization overload (Zaki, 2008). Hierarchical Mobile IPv6 (HMIPv6) and Fast Handover for MIPv6 (FMIPv6), both are MIPv6’s enhancements. The primary cause of packet loss resulting in performance degradation of standard Mobile IPv6 (MIPv6) is the handover latency (Alnas, et al, 2010). Therefore, when there is a handover for Mobile Node (MN), it would cause packet loss. It will be a big problem through sessions of real-time between the Mobile Node (MN) and the Correspondent Node (CN). The focus of this research will be to reduce packet loss in Fast Handover for Mobile IPv6.

1.2 Motivations

During the last two decades, there has been remarkable development in the wireless communications. For example, the GSM (Global System for Mobile Communications), which was developed during the 1990’s, is now the most successful digital mobile telecommunications system (Shah and Chatterjee, 2004).

The main aim is to allow mobile nodes to keep communication with other hosts while roaming between different networks. Roaming occurs when a node moves from one access network to another; it constitutes physically moving from one network to another. Standard protocols like IPv4 and IPv6 will result in disconnection of ongoing communication. Mobile IP allows host to perceive minimum disruption during movement and then continue communication.

Mobile IP has been developed to provide mobility to the host, which changes their point of attachment; however, the idea was that the application on the host could survive the handover delays. Mobile IP provides mobility by introducing two IP addresses for the mobile hosts as “Mobile Node” (MN), a static IP address called as “Home Address” (HoA) which is assigned by the home network, with this IP the host is recognized globally. Another IP called as “Care of Address” (CoA) which is a temporary IP address assigned by the visiting network until nodes stays in the foreign network. A special mechanism of mapping between these two IP addresses is used to send packets to the host’s CoA to allow communication between previous peers and new peers. To communicate between two networks, devices such as routers are used and must be configured with special parameters to handle mobility functions. The router used at home network is called as “Home Agent” (HA) and the router at foreign network is called as “Foreign Agent” (FA). Either any node fixed or mobile communicating with this node is called as “Correspondent Node” (CN). Whenever the MN moves from its current domain to a new domain, it performs a procedure called handover. This procedure produces latency that affects the overall performance and causing packet loss and signaling overhead.

1.3. Problem Background

Many researchers worked on similar ideas before, some of them designed real solutions while others only attempted some, and many ways were used to solve the problem. This research will mention some of them briefly.

The Mobile IPv6 provides a lot of enhancements, but it still has some weaknesses in managing the layer 3 handover of the Mobile Nodes. When the MN moves from its current domain to a new domain, it performs a procedure called handover. This procedure produces latency which affects the overall performance and causing packet loss and signaling overhead. When a Mobile Node (MN) is away from home, it sends information about its current location to a Home Agent (HA). The HA intercepts a packet addressed to the Mobile Node and tunnels them to the Mobile Node’s present location. An efficient and deployable protocol for handling mobility with IPv6, and to minimize the control traffic needed to affect mobility (Zaki, 2008). The handover period in Mobile IPv6 is too or very long to complete, packets are dropped specially for time-sensitive applications.

The author in (Koodli, 2002, and Koodli, 2009) assumed that a New Access Router (NAR) may receive packets forwarded by the Previous Access Router (PAR) of an MN even before the MN attaches itself to the NAR. However, unless the NAR buffers the packets, loss of packets may occur. The same condition applies when a Fast Binding Update (FBU) is sent after the MN is attached to the NAR, where unless they are buffered, the packets sent to the PAR will be lost. Hence, an option is provided in the Handover Initiate message to indicate a request for packets to be buffered in the NAR. Should the PAR requests for the feature, buffering support needs to be provided by the PAR itself. However, there is a problem in the generation of a triangle routing between the previous and the new access routers as well as the Correspondent Nodes (CN).

The proposal for a scheme for an enhancement of the buffer management in the Fast Handover protocol by (Yao, and Chen, 2004) contains two parts. Figure 1.1 depicts that in a handoff process, buffers are used in both PAR and NAR while only the NAR buffers the packets in the original Fast Handover, thus improving the network's total utilization of buffers. In the second part, the services in a handoff process are defined into three types based on the packets' traffic characteristics to ensure that the packets are treated accordingly. Packet loss can be reduced through buffering. Nevertheless, if the number of Mobile Nodes those attached to the router increased, the efficiency of a router will be affected by the overhead on the router. Though the proposed buffer management scheme mentioned above is meant to improve the utilization of buffer for the Predictive mode for F-MIPv6, there is the problem regarding the implementation of the architecture.

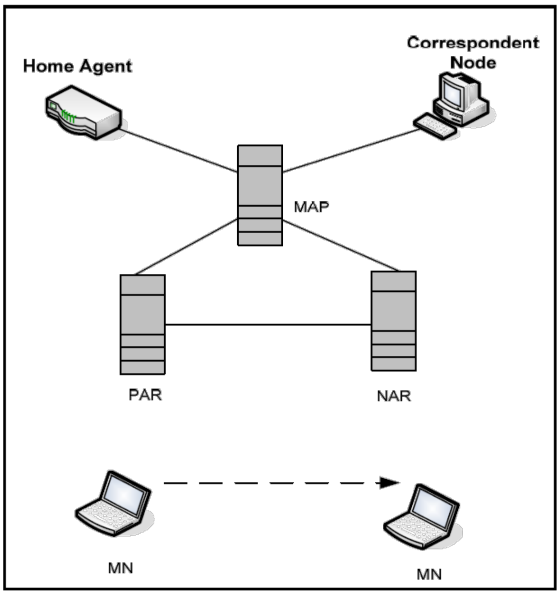

Figure 1.1 Buffering on PAR and NAR in FMIPv6 scenario (Zaki, 2008)

Alnas, et al, proposed the second method or approach to solve the problem of packet loss in 2010. They proposed Mobile IPv6 with Fast Handover that allows a Mobile Node (MN) to quickly detect the IP layer that it has moved to a new subnet by receiving link-related information from the link-layer. Moreover, it collects anticipant instruction around the new Access Point (NAP) and the associated subnet prefix when the MN is still linked to the previous Correspondent Node (CN). The paper suggested an improved fast handover schema in MIPv6 via accessing the link-layer data. The fast handover protocol is tailored to reduce the packet loss through a handover. This approach can avert the packet loss in Mobile IPv6 (MIPv6). It is quite obvious that FMIPv6 has better performance under handover latency and packet loss because that fast handover protocol is tailored to eliminate packet loss and latency during handover. Two factors control number of packet lost. The first is buffer size used for packet storage for potential handover, and the second is the rate of sending, when no buffer is used like Standard Mobile IP (S-Mobile IP) the number of packet lost gets reduced, meaning that if the buffer used is big enough, no packet loss can occur.

The buffer size can be adjusted with respect to the sending rate, i.e. size increase as sending rate increases. The new link connection on the available network interface is always established the moment MN senses a new available network. It is quite clear that FMIPv6 approach functions more efficiently with respect to the handover latency and packet loss. Both handover latency and packet loss prevention are reduced under this approach utilization. The algorithm can also be tested for different mobility models in IPv6 network with neighbor data accessed. In addition, the performance can be evaluated when running fast handover for MIPv6 on Wimax networks.

Recently, to alleviate the problem of packet loss, packet buffering has been implemented in the access point since it manages fewer mobile nodes than access router (Lee, et al., 2008, Lee, et al., 2009, and Hur, et al., 2007). Note that the buffer space is limited in a router or access point. Therefore, the arriving packets will be lost after the buffer is full. This means that packets may be dropped regardless of the service characteristics during packet buffering for handover. For real time service such as IP telephony, for example, packet loss is often unacceptable. To satisfy the requirements of respective service, thus, the packets have to be buffered differently according to the service characteristics during handover.

There exist various approaches of packet buffering. The buffering is a technique which can be used to reduce the handover latency which intern reduces the packet loss. The double packet buffering approach (Yao, and Chen, 2004) was proposed to reduce the loss of high priority packets by buffering them in both the previous and new access router. However, the Fast Mobile IP has to be modified because additional operations are required for performing the double packet buffering. LT-Buffer (Link-Triggered Buffer) mechanism was pro-posed in (Lu, Tie, and Hong, 2007), which utilizes the advantages of cross-layer interactions between the link layer and network layer so that packet loss can be reduced.

Packet losses are closely related to the handover latency and buffer size used for packet buffering. In the case of increased handover latency or decreased buffer size, packet losses will be increased.

1.4 Problem Statement

This research mainly focused on packet loss issues during handover process in mobile wireless networks. In general, Loss of packets in mobile networks as well as wireless networks may be caused by network congestion, handover or bit errors in any wireless channel which are error-prone. However, the major reason of packet loss is handover where a broken link to the original access point while the packets are still routed to the access point as the packets might be dropped by that access point (Zaki, 2008).

While a Mobile Node (MN) is moving from one subnet to a new subnet, packets sent by a Correspondent Node (CN) cannot be received until the MN obtains its new address. This problem causes a huge setback in real time traffic

Thus, a new algorithm that called adaptive packet buffering tuning algorithm based on priority and traffic throughput in order to reduce packet loss in Fast Mobile IPv6 will be proposed. The evaluation of the proposed algorithm will be provided through simulated experiments in order to compare its efficiency to existing and known schemes.

1.5 Research Questions

According to the explained issues in the previous sections, research questions that will be addressed in this research are as follows:

1. How to adjust the adaptive packet buffering tuning algorithm that deal with reducing packet loss in FMIPv6?

2. How to develop the adaptive packet buffering tuning algorithm based on priority and traffic throughput to reduce packet loss during handover process in FMIPv6?

3. How to evaluate the performance and efficiency of the proposed solution adaptive packet buffering tuning algorithm in order to reduce packet loss in the Fast Mobile IPv6 by way of comparison?

1.6 Research Aim

This research aim is to reduce packet loss in FMIPv6 by utilizing adaptive packet buffering tuning algorithm based on priority and traffic throughput when the Mobile Node (MN) move from one network to the another new network.

1.7 Research Objectives

The precise goals of this research are as follows:

1. To modify the proposed adaptive packet buffering tuning algorithm that deal with reducing packet loss in FMIPv6 by buffering the packets rather than dropping them simply.

2. To develop the adaptive packet buffering tuning algorithm based on priority and traffic throughput to reduce packet loss during handover process in FMIPv6.

3. To evaluate the efficiency of the proposed algorithm adaptive packet buffering tuning algorithm in order to reduce packet loss in FMIPv6 by way of comparison.

1.8 Scope of the Study

This research focuses on reducing packet loss in Fast Mobile IPv6. In order to achieve the research objectives, the scope of this research covers following points.

1. This study will focus on implementation of the proposed algorithm in the FMIPv6 environment.

2. This study will focus on reducing packet loss in FMIPv6 by using adaptive packet buffering tuning algorithm based on priority and traffic throughput.

3. This research will use network simulation OMNET++ in order to evaluate the proposed algorithm adaptive packet buffering tuning algorithm.

1.9 Research Contribution

The following are the planned key contributions of this research:

1. Developing the adaptive packet buffering tuning algorithm based on priority and traffic throughput to reduce packet loss in FMIPv6.

2. Modifying the proposed algorithm in order to reduce the packet loss in the Fast Mobile IPv6 by buffering the packets better than dropping them.

3. Evaluating the performance and efficiency of the proposed solution adaptive packet buffering tuning algorithm in order to reduce packet loss in FMIPv6. By using the metrics such as packet loss, delay, throughput, and traffic received.

1.10 Significance of the Study

In this, research a mobility model was based on a Fast Handover for Mobile IPv6. Furthermore, proposing the algorithm called adaptive packet buffering tuning algorithm based on priority and traffic throughput, communication in FMIPv6 will be made to provide reliability in FMIPv6 through reducing the number of packet loss in the communication between a Mobile Node (MN) and the Correspondent Node (CN).

1.11 Research Organization

This research consists of five chapters starting by chapter 1 and ending by chapter 6 as follows:

- Chapter 1: It presents the introduction to the study, problem background, motivation, aim, objective, scope, contribution, and significance of the study.
- Chapter 2: It gives the literature reviews that was done regarding on reducing packet loss in Fast Mobile IPv6, several existing techniques

also be defined and discussed. In the end a discussion of proposed solution is presented.

- Chapter 3: It provides research methodology flow used in this research. This has been done by provide the general framework of the research represented via stages.
- Chapter 4: It presents discussion in details about the design of APT proposed algorithm used in this study that explains in-depths on how the packet loss in FMIPv6 will be reduced and implemented; and the simulation setup. Moreover, a brief overview about the OMNET++ simulation and its mean features. It discusses on the methodology and research design this chapter also provides details on the simulation process. Also, it discussed the performance metrics.
- Chapter 5: It presents the experimental results and implements have been presented and discussed in order to evaluate the proposed APT algorithm in this research. Also, compared the APT algorithm with ALT algorithm by using performance metrics.
- Chapter 6: The conclusion of this research with future work has been presented in this chapter.

REFERENCES

Alnas, M., Awan, I., and Holton, R.D.W.;. (2010). Performance Evaluation of Fast Handover in Mobile IPv6 Based on Link-Layer Information. *The Journal of Systems and Software.* , 1-7.

Bentham, J. (2002). *TCP/IP LEAN Web Servers for Embedded Systems 2nd edition.* CMP Books.

Byungjoo Park, Y.-H. H. (Sep 2006). EAP: New Fast Handover Scheme based on Enhanced Access. *IJCSNS International Journal of Computer Science and Network Security , VOL.6 No.9B,* , 70.

Chen-Hua Shih and Yaw-Chung Chen. (August 2010). A FMIPv6 Based Handover Scheme for Real-Time Applications in Mobile WiMAX. *Journal of Networks, VOL. 5, NO. 8.*

Ganz, A. G. (2004). *Multimedia Wireless Networks technologies, standards, and QoS"1st edition.* Prentice Hall.

Gross, D., et al.,. (2008). *Fundamentals of Queueing Theory, Fourth Edition.* Wiley.

Hersent, O. G. (2000). *IP Telephony Packer-based multimedia communications systems", 1st edition.* Addison-Wesley.

Hossain, A. and Kanchanasut, K. (October 2005). A Handover Management Scheme for Mobile IPv6 Networks. *In Proceedings the 14th IEEE Computer Communications and Networks International Conference* , 34-38.

Hur, K., et al.,. (March 2007). Priority forwarding for improving the TCP performance in mobile IP based networks with packet buffering. *Computer Communications, vol. 30, no. 6* , 1337-1349.

Johnson, D. and Perkins, C. (July 2000). Mobility Support in IPv6. *Internet Draft, IETF Mobile IP Working Group.*

Johnson, D., Perikins, C., and Arkko, J.,. (2003). Mobility Support in IPv6. *Internet draft, ietf* .

Johnson, D., Perkins, C., and Arkko, J. (June 2004). Mobility Support in IPv6. *IETF RFC 3775*.

Karagiannis, G. (1999). Mobile IP State of the Art Report. *Ericsson* .

Koodli, R. (2002). Fast Handovers for Mobile IPv6. *Internet Draft* .

Koodli, R. (July 2005). Fast Handoffs for Mobile IPv6. *RFC 4068. IETF Network Working Group*.

Koodli, R. (2007). Fast Handovers for Moblie IPv6. *Internetdraft* .

Koodli, R. (July 2009). Mobile IPv6 Fast Handovers. *IETF RFC 5568* .

Kyunghye Lee and Youngsong Mun. (2007). An Efficient Macro Mobility Scheme Supporting Reactive Fast Handover Mode in HMIPv6. *Springer-Verlag Berlin Heidelberg, O. Gervasi and M. Gavrilova (Eds.): ICCSA 2007, LNCS 4706, Part II* , 237–246.

Lee, S., et al.,. (May 2009). A Handoff Packet Marker for DiffServ in Mobile IP based Networks with Packet Buffering. *IEEE Trans. Consumer Electronics, vol. 55, no. 2* , 438-446.

Lee, S., et al.,. (Aug. 2009). A Packet Forwarding Controller for Mobile IP-based Networks with Packet Buffering. *IEEE Trans. Consumer Electronics, vol. 55, no. 3* , 1344-1350.

Li, T and Leith, D. J. (2008). Adaptive Buffer Sizing for TCP Flows In 802.11e WLANs. *IEEE Communications Letters, to appear, Irish Research Council for Science, Engineering and Technology and Science Foundation Ireland Grant 03/IN3/I396.*

Lu, H., Tie, X., and Hong, P. (July 2007). A Novel Buffer Mechanism for Fast Handovers in Mobile IPv6. *in Proc. 2007 IEEE Int. Conf. Wireless and Optical Communications Networks.*

Lundberg, J. (May 2003). An Analysis of The Fast Handovers for Mobile IPv6 Protocol. *IEEE CCECE 2003. Canadian Conference on, Volume 2* , 4-7.

Malki, K., and Soliman, H. (July 2005). Simultaneous Binding for Mobile IPv6 Fast Handovers. *IETF draft-elmalki-mobileip-bicasting-v6-06-txt* .

McNair, J., Akyildiz, I. F., and Bender, M. D. (2001). Handoffs for Real-Time Traffic in Mobile IP Version 6 Networks. *IEEE* , 3464-3467.

OMNET++. (2011, June). *Omnet++ simulator*. Retrieved from OMNET++ Discrete Event Simulation System. [Online]: http://www.omnetpp.org/.

Perkins, C. (1998). Mobile Networking through Mobile IP. *IEEE Internet Computing, Vol: 2, Issue: 1* , 58-69.

Perkins, C. and Johnson, D. (September 2001). Route Optimization in Mobile IP. *Mobile IP Working Group* .

Perkins, C. (March 2007). IP mobility support for IPv4. *Internet Draft* .

Perkins, C. (October1996a). IP mobility support for IPv4. IETF RFC 2002, Internet Draft.

Pierre, C. M. (March 2008). An Analytical Framework for Performance Evaluation of IPv6-Based Mobility Management Protocols," *IEEE Transactions on Wireless Communications, VOL.7, NO.3.*

Pierre, C. M. (March 2008). An Anlaytical Framework for Performance Evaluation of IPv6-Based Mobility Management Protocols. *IEEE Trans. Wireless Communications, vol. 7,* (pp. 972-983).

Prasad, Anand, R., and Neeli R. Prasad. (2005). *802.11 WLANs and IP Networking Security, QoS, and Mobility*. United States of America: Library of Congress Cataloging-in-Publication Data.

R. Li, J. L. (January 2008). An Enhanced Fast Handover with Low Latency for Mobile IPv6. *IEEE Trans. Wireless Communications, Vol 7, No. 1*, 334-342.

Ramani, I., Savage, S. (March 2005). SyncScan: practical fast handoff for 802. 11 infrastructure networks. *In: Proceedings of the IEEE Infocom Conference, Miami, FL*.

Schmidt, T.C.,Wahlisch, M., Cycon, H.L., and Palkow, M. (2003). Mobility Support in Real-time Video Communication. *The society for Modeling and Simulation International, California* , 72-77.

Shah, R. and Chatterjee, M. (2004). A hierarchical architecture to Integrate GSM and Mobile IPv6. . *In Proceedings IEEE Wireless Communications and Networking Conference, IEEE, Vol: 1* , 138-143.

Shanmugam R., Padamini R., and Nivedita S. (2002). *Using TCP/IP, 2nd edition.*

Shin, M., Arbaugh, W. (April 2003). An empirical analysis of the IEEE 802.11 MAC layer handoff process. . *ACM Computer Communications Review 33* .

Siksik, M., Alnuweiri, H. and Zahir, S. (2005). Performance Evaluation of Micro-Mobility Management Using Mobile IPV6. . *In Proceedings International Conference on Wireless Networks, Communications and Mobile Computing, IEEE, Vol: 1* , 316-322.

Soliman, H., Castelluccia, C., El-Malki, K. and Bellier, L. (June 2003). Hierarchical Mobile IPv6 mobility management (HMIPv6). *IETF Mobile IP Working Group*.

Tsirtsis, G., Yegin, A., Perkins, C., Dommety, G. , EL-Malki, K., and Khalil, M. (September 2002). Fast Handovers for Mobile IPv6. *Internet Draft, work in progress, http://tools.ietf.org/html/draft-daley-magma-mobile-00.*

Wang. Y. H, Hsu. C. P, and Lai. J. Y, (2004). A Mobile IPv6 Based Seamless Handoff Strategy for Heterogeneous Wireless Networks. *Fourth International Conference on Computer and Information Technology (CIT'04)* , 600-605.

Wu, X., and Nie, G. (2009). Performance Analysis and Evaluation of Handover in Mobile IPv6. *International Symposium on Intelligent Ubiquitous Computing and Education*.

Y Mun, S. R. (2009). Performance Analysis for FMIPv6 considering Probability of Predictive Mode Failure. *International Conference on Computational Science and Its Applications.*

Yao, W-M., and Chen, Y-C. (2004). An Enhanced Buffer Mnagement Scheme for Fast Handover Protocol. *Distributed Computing Systems Workshop.*

Zaki, S. M. (2008). *Reducing Real-Time Traffic Packet Loss in Mobile IPv6 Using two Tier Buffer*. Faculty of Computer Science and Information Systems, University Technology Malaysia, Master of Science (Computer Science).

Zhao, Y., and Nie, G. (2009). A Scheme for Reducing Handover and Packet Loss in Heterogeneous Mobile IPv6 Networks. *International Conference on Future Computer and Education* .

Zhao, Y., and Nie, G. (2009). Analysis and Evaluation of an Enhanced Handover Scheme in Hierarchical Mobile IPv6 Networks. *International Conference on Future Computer and Communication* .

Zhong, F., Yeo, C. K., and Lee, B. S. (2010). Enabling inter-PMIPv6-domain Handover with Traffic Distributors. *Journal of Network and Computer Applications* .